Facultad de Ingeniería en Electricidad y Computación

5G cellular system: A brief review of architecture, use cases, and enabling technologies

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July 2020

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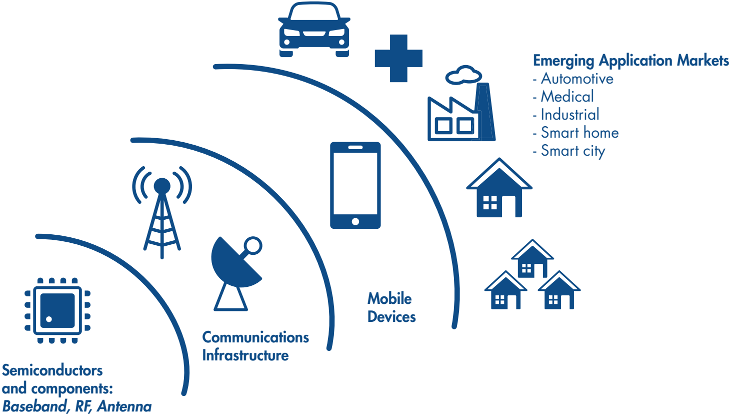
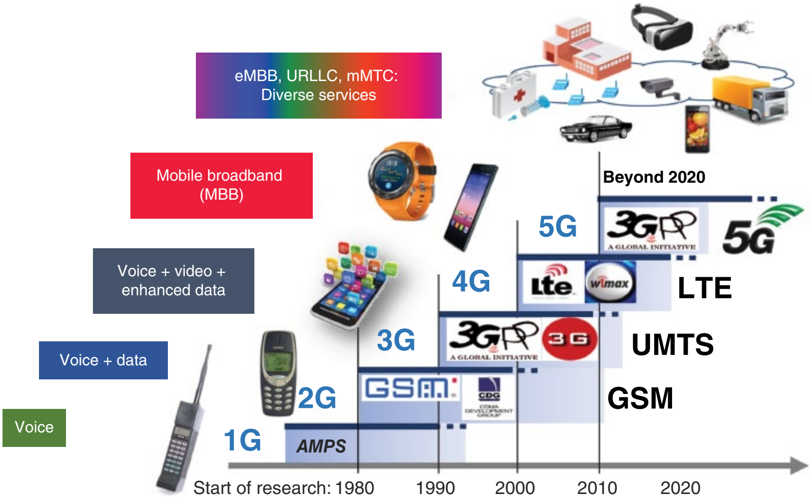
- Motivation
- KPIs, capabilities, and use cases
- Architecture
- Future wireless communications

What is 5G?

5G (5th generation wireless systems) is the next major phase of mobile telecommunications standards. The scope of 5G will ultimately range from mobile broadband services to next-generation automobiles and connected devices.



Cellular communications generations and 5G - Main drivers



5G motivation on **data rates**

More applications demand high data rates

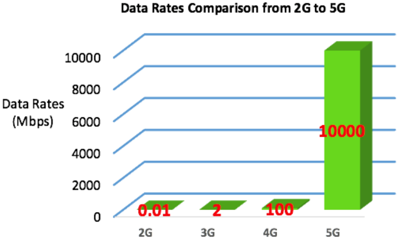
- HD video streaming
- Virtual reality (VR)
- Autonomous vehicles

Peak data rates

- Best-case scenario (at cell-center)
- ≈ 20 Gbps for 5G
- 100 times faster than 4G LTE

Cell edge data rates

- Worst-case scenario
- ≈ 100 Mbps for 5G



5G motivation on **latency**

Interactive applications requires very low latency

- Autonomous vehicles
- Tactile internet
- Multi-user online gaming

Mission-critical communications needs low latency on

- Real-time control
- Automation of dynamic processes (e.g. energy distribution, intelligent transport systems)

5G target on latency - 1ms

- 10 ms in 4G LTE

5G motivation on **energy consumption**

- Green Communications must be realized in 5G
  - Energy consumption per bit should fall by 1000 times
- Battery lifespan of mobile devices needs to be prolonged for more power-hungry applications
- Reduce the operational expenditure (OPEX) of Mobile Network Operators (MNO)
  - Energy consumption has a very high impact on the overall operational cost of telecom providers
  - BSs account for almost 60% of the overall energy consumption of existing cellular networks
  - Investments for new traffic demands have no proportional revenue when there is low energy efficiency in the network
- Energy Harvesting from renewable resources: Solar/wind power, etc.

5G motivation on **scalability**

Devices will reach 50 billion by 2023

- Internet of Things
- Healthcare devices

Location-aware communications will benefit

- Mission-critical services
- Energy efficiency
- Throughput increase

5G motivation on **connectivity**

5G should support mobility of up to 500 km/h

- High-speed railway
- Vehicle-to-vehicle communications

Connection density is 1 million/km^2

- Mission-critical services
- Energy efficiency
- Throughput increase

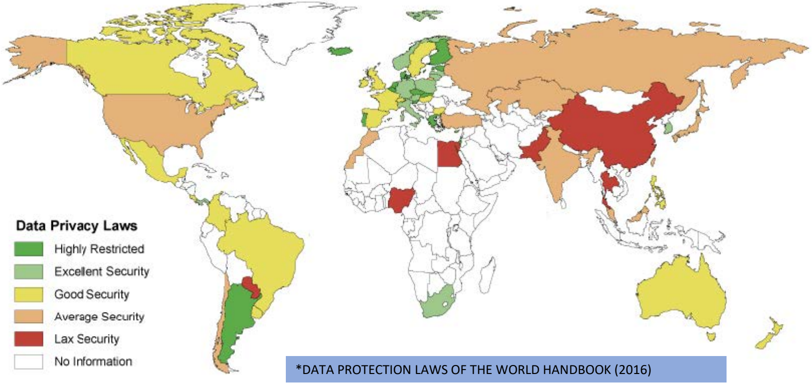
Mobility on demand (MoD) can support a wide range of mobility

- Static utility meters
- Walking pedestrians
- High-speed trains

5G motivation on **security and privacy**

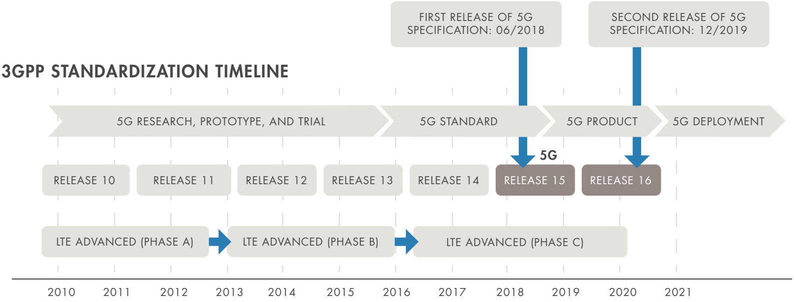
Great challenges on data security and user privacy

- Mobile payment
- Cloud storage, etc.



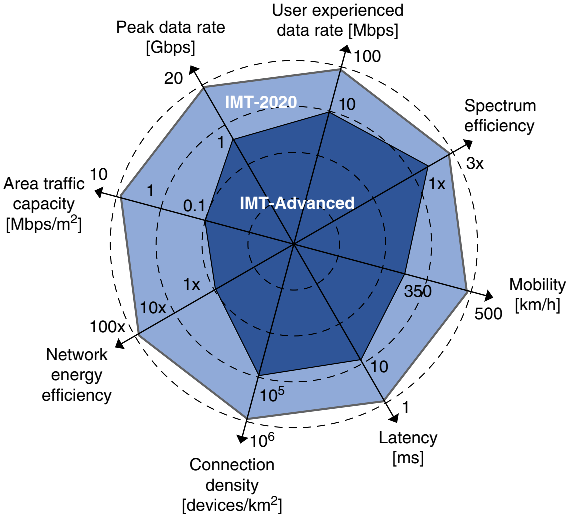
*DATA PROTECTION LAWS OF THE WORLD HANDBOOK (2016)

5G timeline

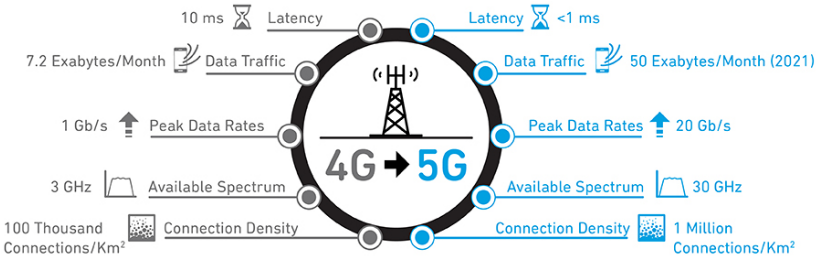

FIRST RELEASE OF 5G SPECIFICATION: 06/2018
SECOND RELEASE OF 5G SPECIFICATION: 12/2019
3GPP STANDARDIZATION TIMELINE
5G RESEARCH, PROTOTYPE, AND TRIAL
5G STANDARD
5G PRODUCT
5G DEPLOYMENT
5G
RELEASE 10
RELEASE 11
RELEASE 12
RELEASE 13
RELEASE 14
RELEASE 15
RELEASE 16
LTE ADVANCED (PHASE A)
LTE ADVANCED (PHASE B)
LTE ADVANCED (PHASE C)
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021

Key capabilities

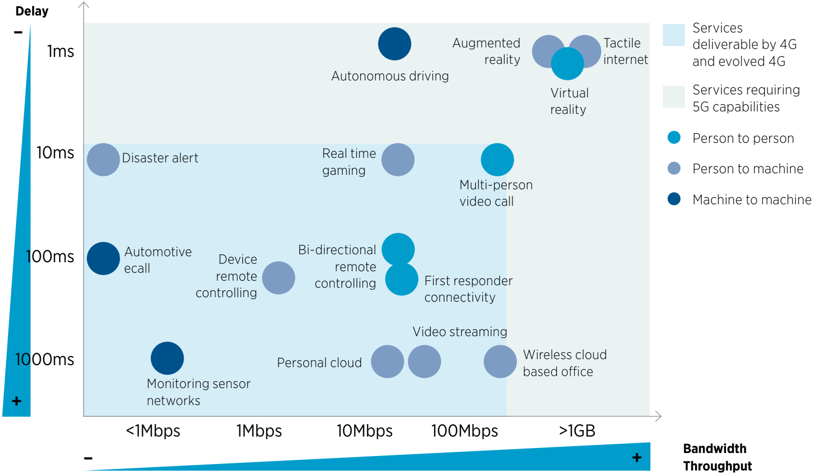
International Mobile Telecommunications (IMT) - Focus group in ITU-R



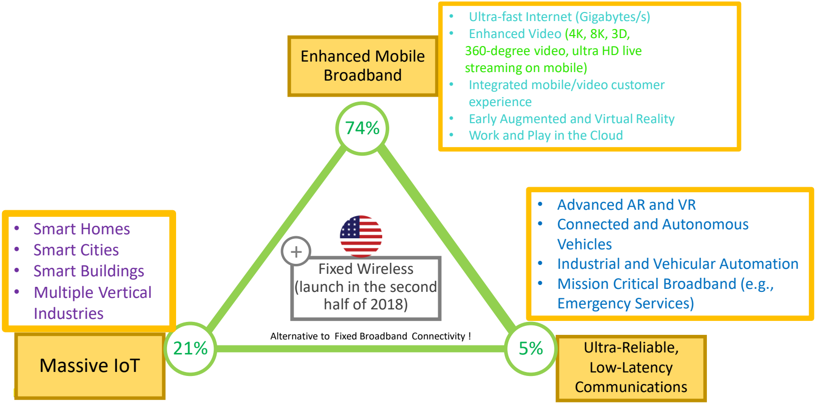
Comparing 4G and 5G



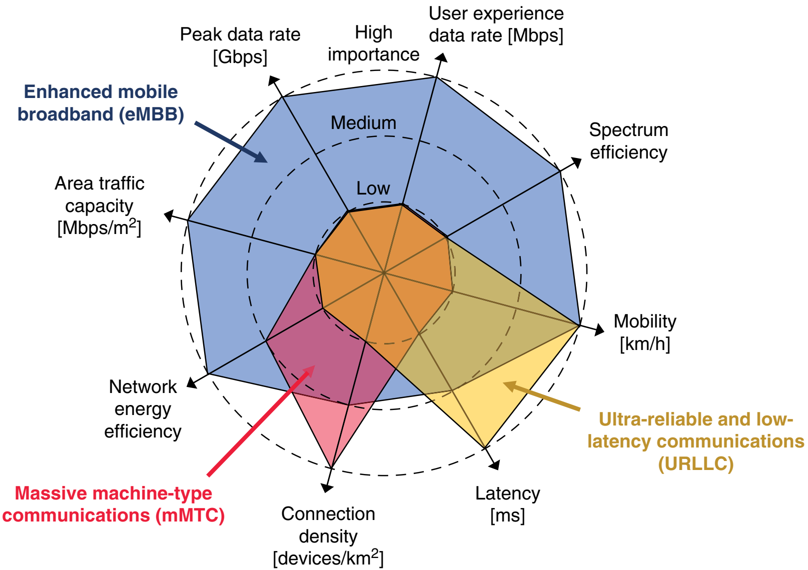
5G latency and speed



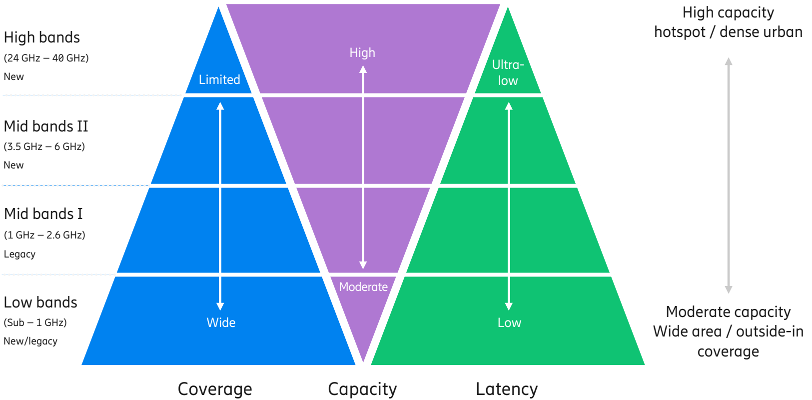
Priority use cases in 5G deployments



Importance of KPIs for different service types



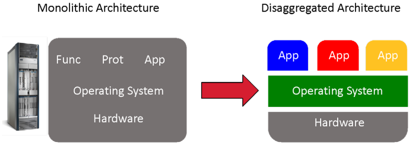
Spectrum availability and trade-off



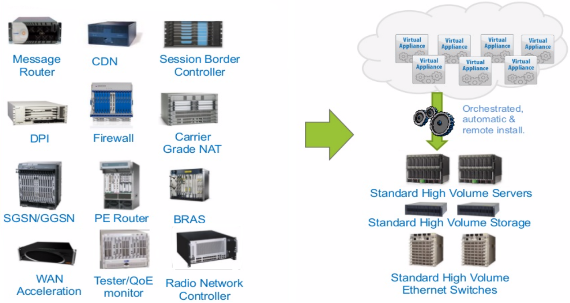
Source: IEEE – A survey on Low latency towards 5G RAN, Core network and Cashing solutions.

Cloud-native Architecture

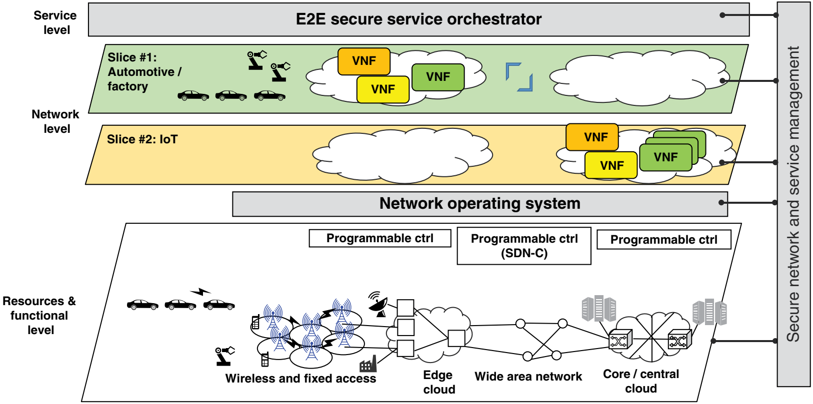
Disaggregation



Virtualization



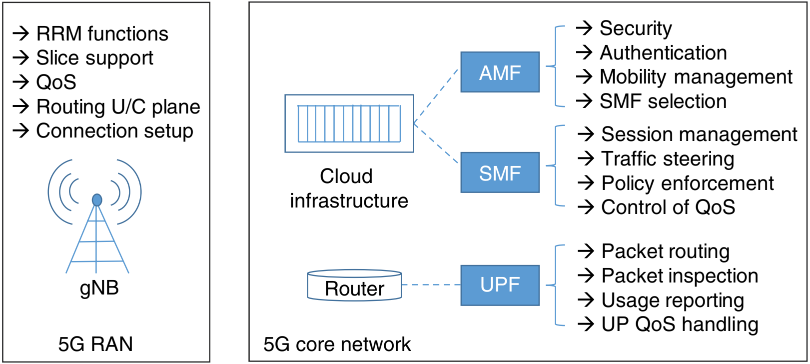
End-to-end architecture overview



Aim: Architecture flexibility, heterogeneous accesses, vertical business integration

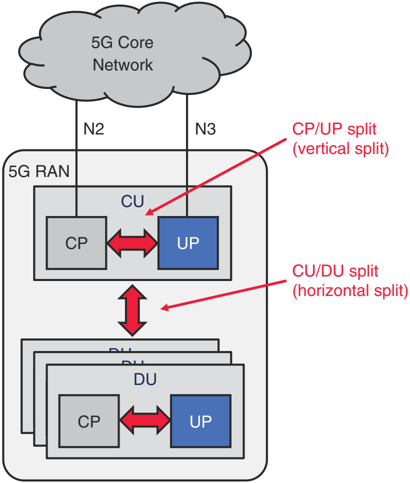
Enablers: SDN; NFV; Modularization; Network Slicing; Network Softwarization; Multi-tenancy; Multi-Access Edge Computing

Functional split between NG-RAN and 5G core



Logical nodes
RRM: Radio Resource Management - AMF: Access and Mobility Management Function
SMF: Session Management Function - UPF: User Plane Function

Functional split NG-RAN



N2 - N3
Next generation interfaces for connecting logical nodes between NG-RAN and 5G Core

Control plane / user plane split

- Enables the introduction of SDN
- Optimization
- Consistent control in multi-vendor networks (interference management)
- Costs savings

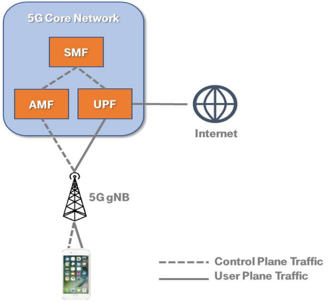
Centralized units / decentralized units split

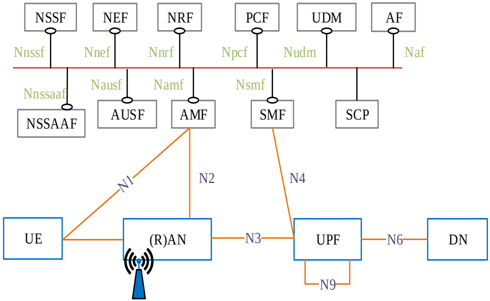
- Centralized resource management, performance gains
- Shift functions to different locations based in use cases requirements - multi-access edge computing (MEC)
- Adapt RAN processing to different deployments and infrastructures

Modularization

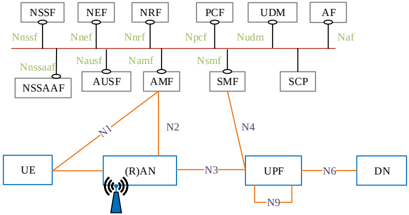
Network elements split into basic modules or Network Functions (NFs)

- Formalizes the NFs as founding logical elements
- Achieve the paradigm of convergent network
- Next generation interfaces (inter-NF interfaces; CP-UP interfaces)





Modularization 5G core



Namf, Nsmf, · · · : service-based interfaces used within the CP
N1, · · · , N9: reference points (interactions among NFs)

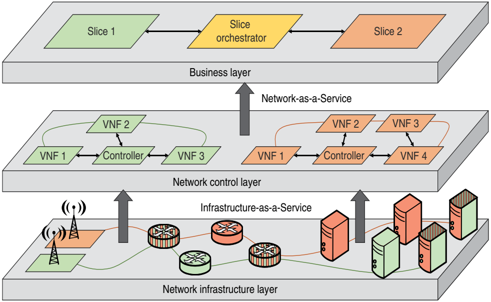
NSSAAF: Network Slice Specific Authentication and Authorization Function
AUSF: Authentication Server Function
AMF: Access and Mobility Management Function
SMF: Session Management Function
SCP: Service Communication Proxy
NSSF: Network Slice Selection Function
NEF: Network Exposure Function
NFR: Network Function Repository
PCF: Policy Control Function
UDM: Unified Data Management
AF: Application Function
UPF: User Plane Function
DN: Data Network

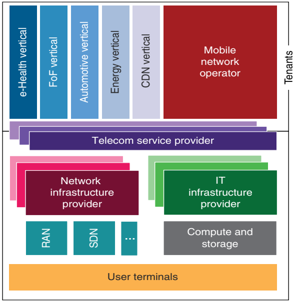
Main functionalities

- **AMF** mobility management, NAS ciphering and integrity protection, lawful interception, access authentication and authorization, security anchoring, security context management
- **SMF** session management, UE IP address allocation and management UP function selection and control, policy enforcement and QoS, roaming functionality
- **AUSF** authentication and authorization functionalities
- **NEF** collect, store and securely expose the services and capabilities provided by 3GPP NFs
- **NFR** maintaining and providing the deployed NF instances, support the service discovery function
- **UPF** anchor point for intra- and inter-RAT mobility, packet routing and forwarding, UP QoS handling, traffic accounting and reporting

Network slicing & Multi-tenancy

Network slice: Independent logical network shaped by the interconnection of a subset of NFs, composing both CP and UP, and which can be independently instantiated and operated over physical or virtual infrastructure.
Different **tenants** can get their own network customized for a specific purpose.

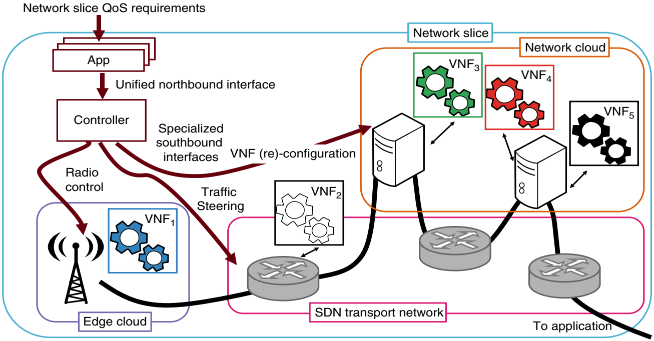




Network slicing calls for a novel architecture capable of flexibly orchestrating and configuring all the resources, functions, and entities used by a network slice → Network softwarization

Network softwarization

Bring the **network programability** beyond SDN: the SDN principles are extended to all control and data layers as well as management functions deployed in mobile networks

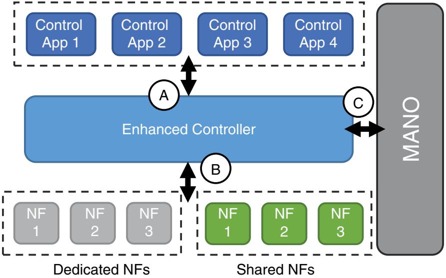


Enhanced Controller

1. Networking control functions (e.g., mobility and session management, and potentially QoS/QoE control)
2. Connectivity control functions (mainly packet forwarding or SDN-based packet forwarding)
3. Wireless control functions (e.g., radio link adaptation and scheduling)

Softwarized Network Control

Abstract technology-specific or implementation-specific aspects of the network ecosystem with interfaces towards the MANO stack and to different control applications

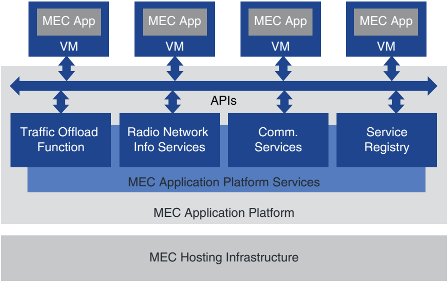


Interfaces

- **A** Enforces the conditions defined by the control apps that must be realized for a given traffic identifier on dedicated NFs and resources to fulfill the targeted SLA with respect to the relevant service policy.
- **B** Controls and configures parameters of the dedicated or shared PNFs and VNFs which implement the NFs on the data path.
- **C** Conveys the control app specific information derived during the translation from high-level tenant requests and established SLAs into the network slice resource provisioning, NFs logic, and lifecycle parameters.

Mobile or Multi-access Edge Computing

Move applications close to the radio (physically collocated with base stations)

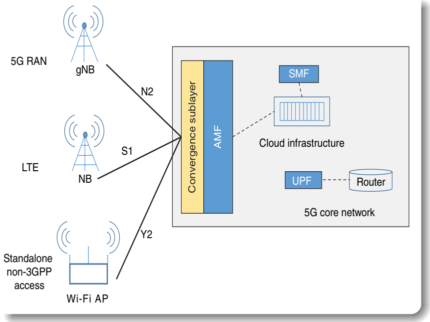


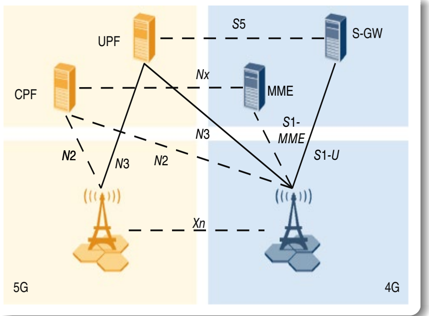
Benefits

1. Reduced E2E latency; communication between UE and app server can be kept in local proximity;
2. Increased networking efficiency;
3. Increased security, because application data can be confined within areas where it is actually needed;
4. Providing applications access to local context and communications-related information (for instance, an application may make use of proximity information among devices).

Access-agnostic 5G core network & Interworking

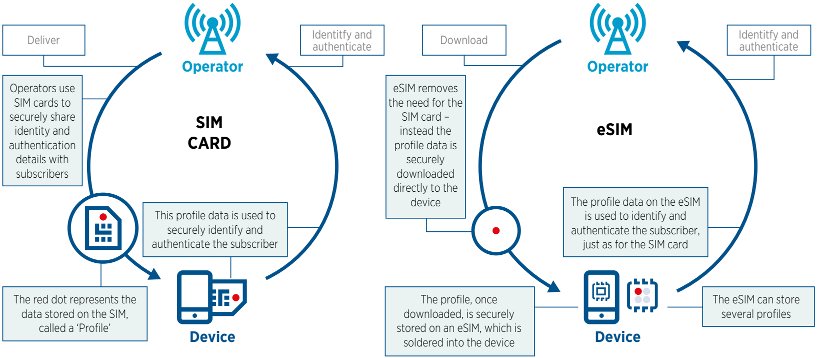
Minimize any dependencies between CN y AN to enable access convergence among 3GPP, non-3GPP, and fixed access networks





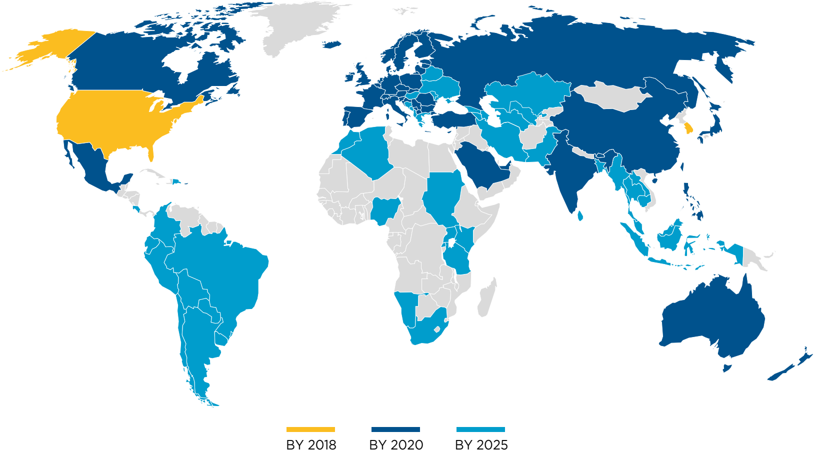
embedded SIM (eSIM)

- Permit remote management of the SIM on mobile devices
- 98% reduction in space over the removable SIM (allowing more room for batteries and modems in 5G devices)
- Smaller form factors and remote provisioning for diverse IoT apps
- Secure, scalable, and minimal friction processes that enable operators to securely authenticate devices on 5G networks

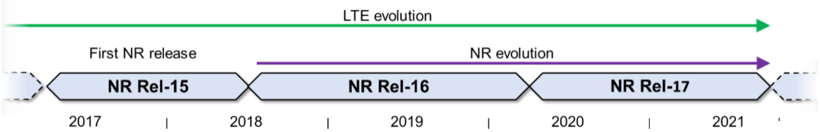


Accelerating 5G momentum

PROJECTED PLANS FOR 5G LAUNCHES PER COUNTRY (SOURCE: GSMA INTELLIGENCE)



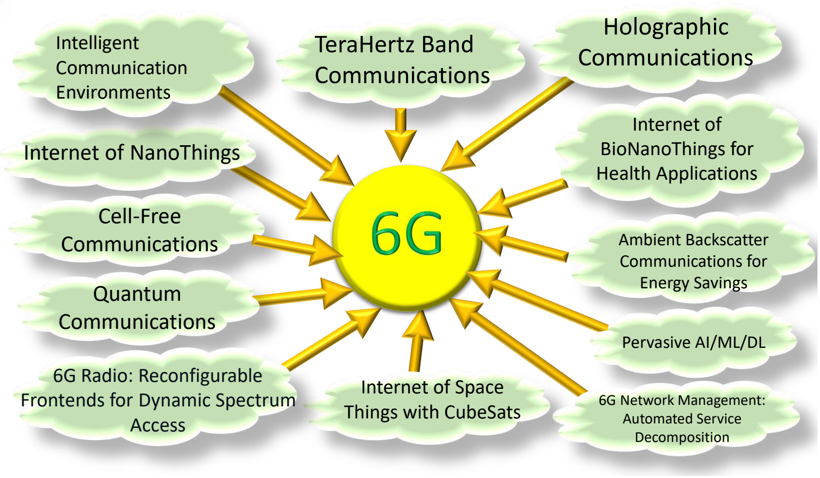
3GPP Release 17



Improve network capacity, latency, coverage, power efficiency, and mobility

- Extending the operation of NR to spectrum above 52.6 GHz to 71 GHz
- Introducing reduced capability NR devices (enabling services with a UE complexity/capability trade-off in-between the conventional high-quality eMBB services and the low-complexity services enabled LTE-MTC and NB-IoT)
- Enhanced Dynamic Spectrum Sharing (DSS)
- Multi-Sim devices
- More advanced Sidelink communications (D2D communications)
- Enabling broadcast/multicast services within NR
- Support for non-terrestrial networks (i.e., a satellite component of NR)

6G - key enabling technologies



Thank you!

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